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A TEST METHOD FOR MEASURING THE STIFFNESS OF COATED FABRICS AT LOW TEMPERATURES

by

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TECHNICAL REPORT

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A test method was developed for use in determining the stiffness of plastic and rubber-coated fabrics at low temperatures by use of a torsional wire apparatus. From the test data obtained with this method, angular twist versus temperature curves can be prepared, and the temperatures at which the relative moduli of the coated fabric are 2,5,10, and 100 times as large as the modulus at room temperature can be determined. The method has been accepted by the American Society for Testing and Materials and has been published as ASTM D3388-75.

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FOREWORD

This project has been accomplished as part of the US Army Materials Testing Technology Program, which has for its objective the timely establishment of testing techniques, procedures or prototype equipment (in mechanical, chemical, or nondestructive testing) to insure efficient inspection methods for materiel/material procured or maintained by AMC.

CONTENTS

OBJECTIVE:

The purpose of this work was to develop a test method to indicate the degree to which rubber or plastic-coated fabrics stiffen during exposure over a range of temperatures from ambient to -67^{o}F, or colder. It was desired that the test method provide a means for measuring wide variations in material stiffness, and provide quantitative results.

BACKGROUND:

One of the most stringent requirements called for on nonmetallic components and accessories of Army weapons is that they remain operational at very low temperatures. This requirement stems from the need for Army materiel to be functional in all global environments.

Tests have been developed and standardized that are satisfactory for determining the capability of solid rubber components to function at low temperatures. ASTM D1053 is the standard method of test for measuring the stiffening of solid rubber at low temperatures. ASTM D1229 is used to measure the capability of solid rubber to recover, at low temperatures, from compressive stresses. ASTM D1329 is used to evaluate the capability of solid rubber to retract at low temperature after having been elongated. ASTM D746 is used to determine the temperature at which a rubber exhibits brittle failure under impact.

Tests have also been developed and standardized by ASTM that are adequate for determining the capability of cellular rubber parts to function at low temperatures. ASTM Methods D1055 and D1056 describe test procedures for measuring the compression-deflection characteristics of cellular rubber at subnormal temperatures.

However, test methods with the rubber-coated fabrics are not adequate. Although ASTM Method D2137 is adequate for determining the temperature at which a coated fabric becomes brittle under impact, no completely satisfactory method is available for measuring the temperature at which a coated fabric becomes too stiff to be useable. The stiffening temperature is nearly always warmer than the brittle temperature, thus the stiffening point is more important to users of coated fabrics than the brittle point is, thus a reliable method for determining the stiffening point is essential. Such a method would be applicable to a broad spectrum of coated fabric items, most of them procured on a very large volume basis. Examples of such items are tarpaulins, gun covers, aircraft covers, pneumatic floating equipment, air supported shelters, gun shield mantle covers, fuel storage containers, and many types of pouches and bags.

Current Federal and Military specifications for rubber or plastic coated fabrics cite five methods for determining the low temperature stiffness of such fabrics. The undesirable features of these methods are given in Table 1. This report covers the work performed in developing a test method to correct the listed deficiences. The method should be adaptable to all coated fabrics regardless of the nature and thickness of the

coating and substrate. The test results obtained from the new method should be reportable in quantitative terms such as moduli so that the stiffness of a variety of coated fabrics can be readily compared.

APPROACH:

This study was directed toward the use of commercially available test equipment. Because one objective of the work was to develop a test method that would provide quantitative measures of stiffness, the search for suitable equipment quite naturally led to the realm of modulus testers. The work of Lindemann[1] pinpointed the search to the torsional tester described in ASTM Method D1053-73.[2] This ASTM method, normally used to measure the stiffness of rubber specimens ranging in thickness from 0.060 inch to 0.125 inch, was modified by Lindemann to accommodate polymer films in the 20 to 30 mil thickness range. The approach taken, in the study reported herein, followed the techniques of Lindemann in attempting to further modify the ASTM method to accommodate coated fabrics over the thickness range from 0.004 to 0.100 inch. Means were sought to increase the sensitivity of the tester so that it could be used with very thin materials. Methods that were studied to increase sensitivity included the use of longer torsion wires than are normally used and the increasing of specimen width and length.

RESULTS AND DISCUSSION:

The three torsion wires that are a part of the ASTM D1053 test equipment have torsional constants of 0.125, 0.500 and 2.000 gf. cm/degree of twist. Even the most sensitive of these wires (0.125 gf. cm/degree) proved to be too insensitive for use with very thin coated fabrics. Thus, more sensitive torsion wires were made from tempered beryllium copper wire in lengths of 5.3 to 5.5 inches and 0.012 inch in diameter. The torsional constants of the new wires were between 0.036 and 0.040 gf. cm/degree of twist. These wires proved to be suitable for use with only a few types of coated fabrics, namely very thin and very flexible materials. The wires were unsuitable for use with the majority of the coated fabrics used in military applications. Typical neoprene and nitrile rubber-coated nylon fabrics exhibited torsional twists at room temperature of less than 120 angular degrees. Angular twists at room temperature, in the range of 120 to 170 angular degrees, are required to obtain meaningful data with the ASTM test.

The attempt to improve the sensitivity of the ASTM test by the increasing of the width of the specimen was successful. The standard specimen

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1. M.D. Lindemann, <u>Appl. Polym. Symp., 10,</u> 73 (1969)
2. <u>Annual Book of ASTM Standards, Part 37,</u> 240 (1975)

free-span length (1.0 inch) was retained, but the width was increased from 0.125 to 0.250 inch. New specimen clamps were fabricated with their faces 0.25 inch wide to facilitate proper contact with the 0.250 inch width specimen. By an increase in width, the effective modulus of the specimens was increased. A large variety of chemical and physical types of coated fabrics were tested and the angular twists at room temperature were within the acceptable range of 120 to 170 angular degrees, as shown in Table 2. These tests were made with standard torsion wires having torsional constants (K) of 0.500 or 2.000 gf. cm/degree of twist.

The reproducibility of the method with the wider than standard specimen, was determined over a temperature range of -10°F to -70°F. Only fair reproducibility was obtained, as shown by the twist versus temperature curves, for duplicate tests, in Figure 1. Prior experience in measuring the stiffness of rubber with the ASTM D1053 test apparatus had indicated that duplicate tests performed by a single operator would give twist values at a given temperature that would vary by no more than ±2 angular degrees. The variation obtained on the coated fabric with the modified equipment was about±6 degrees, as shown in Figure 1.

Investigation of the test equipment during its use at low temperatures showed that, as the torsion head was rotated through 180 degrees, the specimens would not always twist evenly throughout their entire free length; but, these specimens would often fold over (on themselves) when the torque was applied. This phenomenon caused the sample holder to tilt while in the heat-transfer medium, thus this tilting caused erroneous readins of angular twist. To alleviate the tendency of the specimen to fold over on itself required an increase in specimen free length from 1.0 to 1.5 inches. This increase necessitated a modification in the standard test equipment used with ASTM. Thus, this change necessarily required an increase in the length of the center spindle on the D1053 sample holder by one-half inch. The distance between the top and the bottom specimen clamps was adjusted to give the one and one-half inch free span length. Duplicate tests with the 1.5 inch long specimen showed excellent reproducibility, as noted in Figure 2.

A round-robin testing program involving four laboratories was conducted to determine the reproducibility of the new method. Testing was done according to ASTM D1053 with the exception of the change in specimen size (width increased from 0.125 to 0.250 inch and free-span length increased from 1.0 to 1.5 inches). Two specimens of each of the coated fabrics, listed in Table 3, were tested by the measurement of twist in angular degrees at approximately 10°F intervals over the temperature range of -60°F to +60°F. The spread of results over the entire range of test temperatures is shown in Figures 3,4,5, and 6. The values of T_{10} obtained by the four laboratories are also shown in these figures. T_{10} is the temperature at which the modulus of the material under test is ten times larger than the modulus at room temperature. This is the criterion commonly used to indicate the coldest temperature at which a material is useable in an

application involving flexing. The reproducibility of both the twist versus temperature curves and the T_{10} values was satisfactory in the consideration of the fact that the data were obtained by four laboratories.

During the balloting of the test method in ASTM Subcommittee D-11.14 on Low Temperature and Resilience Testing, the suggestion was made that the direction of the weave may have an effect on the flexibility of a coated fabric. Twist versus temperature curves for three specimens of coated Fabric D, cut in three different directions (warp, fill and bias), exhibited good reproducibility in the critical temperature range of -50°F to -30°F, as shown in Figure 7. To eliminate the direction of the cut of the specimen (from becoming a variable for some specialty type coated fabrics) required a change in the test method. This change stipulated that the test specimen be cut on the bias, that is on a 45 degree angle in the direction of the weave. With respect to the use of nonwoven fabrics, the specifying of the direction of specimen cut will not be necessary.

A quantitive means for comparing the stiffness of coated fabrics at low temperatures is provided by determination of the temperatures at which the relative moduli of a coated fabric are 2,5,10, and 100 times as large as they (the moduli) are at room temperature. These temperatures can be calculated by use of the tables in ASTM D1053. The requirement to determine and report these relative moduli was added to the test procedure. The T_{10} values for several of the coated fabrics listed in Table 2 were determined and are shown in Figure 8.

The proposed test method was approved by ASTM on 29 March 1975 and was published[3] the following month under the designation ASTM D3388-75, entitled "Standard Method of Measuring Low-Temperature Stiffening of Fabrics Coated with Rubber or Rubber-Like Materials, by Means of Torsional Wire Apparatus."

CONCLUSIONS:

A test method has been developed for measuring the stiffening of coated fabrics that results from exposure to low temperatures. The method has been proved to provide reproducible results and has been published as an ASTM standard. This method is applicable to both balanced and unbalanced coated fabrics covering a wide range of thicknesses and flexibilities. Test specimens do not require handling during test, and the test apparatus is free from machine variables such as friction of moving parts. The method is nondestructive in nature, that is, it provides stiffness data at ever-decreasing temperatures <u>prior</u> to the onset of cracking, flaking, or other deteriorating effects. The method provides quantitative results that provide comparison of the flexibility of coated fabrics over broad temperature ranges.

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3. Annual Book of ASTM Standards, Part 37,611 (1975)

RECOMMENDATIONS:

Government agencies responsible for the preparation of specifications for coated fabrics should specify the low-temperature flexibility of the materials described within the specifications by citing ASTM D3388 as the method of test, and by citing appropriate requirements. An example of a requirement might be that "the T_{10} of the coated fabric shall be -40°F, or colder."

TABLE I

EXISTING METHODS OF TEST FOR DETERMINING THE STIFFNESS OF COATED FABRICS AT LOW TEMPERATURES.

METHOD	UNDESIRABLE FEATURES
Method 5874 of Fed. Test Method STD. No. 191 - 180^{o} bend plus roller	Does not provide quantitative estimate of stiffness; poor reproducibility because rate of bending is not specified; failure criteria somewhat subjective (flaking or cracking). Sample size (8" x 8") is large.
Mandrel bend (various tests involving different specimen sizes and bending rates)	Poor reproducibility because bending rate is not specified; does not provide quantitative estimate of stiffness.
180^{o} bend (no roller)	Poor reproducibility because bending rate is not specified; does not provide quantitative estimate of stiffness.
Method 5204 of Fed. Test Method STD. No. 191 - Self-weighted cantilever	Various lengths of specimens are required that are dependent upon specimen thickness. Method does not give reproducible results on unbalanced coatings. Rollers do not always turn specimen into roll nip, necessitating excessive handling of specimen.
Method 5206 of Fed. Test Method STD. No. 191 - Cantilever bending	High moduli specimens will not drop through the required 41.5 degree angle unless they are very long. Some coated fabrics must be used in lengths that are more than two feet to obtain a bend of 41.5 degrees.

TABLE 2

ROOM TEMPERATURE TWIST OF COATED FABRICS MEASURED WITH A MODIFIED* ASTM D1053 APPARATUS

	Coating	Substrate	Total Thickness, inch	Weight Oz/yd^2	K (wire), g.cm/deg.	Twist Angular degrees
1.	Neoprene	Cotton	0.015	16	0.5	140
2.	Neoprene	Nylon	0.019	16	2.0	155
3.	Neoprene	Nylon	0.011	10	0.5	141
4.	Neoprene	Nylon	0.022	19	2.0	157
5.	Neoprene	Nylon	0.008	6	0.5	158
6.	Neoprene	Glass	0.006	7	0.5	137
7.	Neoprene	Dacron	0.009	9.5	0.5	149
8.	Vinyl	Nylon	0.014	11	2.0	165
9.	Vinyl	Nylon	0.021	18	2.0	160
10.	Vinyl	Glass	0.014	15.5	2.0	164
11.	Vinyl	Glass	0.006	7	0.5	132
12.	Vinyl	Dacron	0.012	10	0.5	131
13.	Modified Vinyl	Nylon	0.004	2.5	0.5	169
14.	Nitrile	Cotton	0.020	18.5	0.5	165
15.	Nitrile	Nylon	0.017	16	0.5	162
16.	Hypalon	Nylon	0.020	16	2.0	157
17.	Hypalon	Nylon	0.036	32	2.0	142
18.	Butyl	Cotton	0.013	11	0.5	161
19.	Butyl	Nylon	0.024	22	0.5	150
20.	Butyl	Nonwoven polyester	0.022	16	0.5	136
21.	Silicone	Glass	0.032	34.5	2.0	167
22.	Silicone	Dacron	0.015	16	0.5	160
23.	Silicone	Nonwoven polyester	0.017	16	0.5	139
24.	Urethane	Nylon	0.030	28	2.0	155
25.	Urethane	Dacron	0.008	4	2.0	163
26.	EPT	Nonwoven polyester	0.019	14	0.5	121
27.	Polyacrylate	Dacron	0.024	24.5	0.5	149
28.	Polyethylene	Nylon	0.008	4.5	0.5	138
29.	Viton	Nonwoven polyester	0.011	11	0.5	154
30.	Polyurethane	Saran film and nylon	0.043	35.5	2.0	149

*Sample width increased from 0.125 in. to 0.250 in. Sample holders changed to accommodate larger sample.

Figure 1 Reproducibility of Twist vs. Temperature Curves for a Vinyl-Coated Fabric (12, Table 2) (Specimen Length = 1.0 inches)

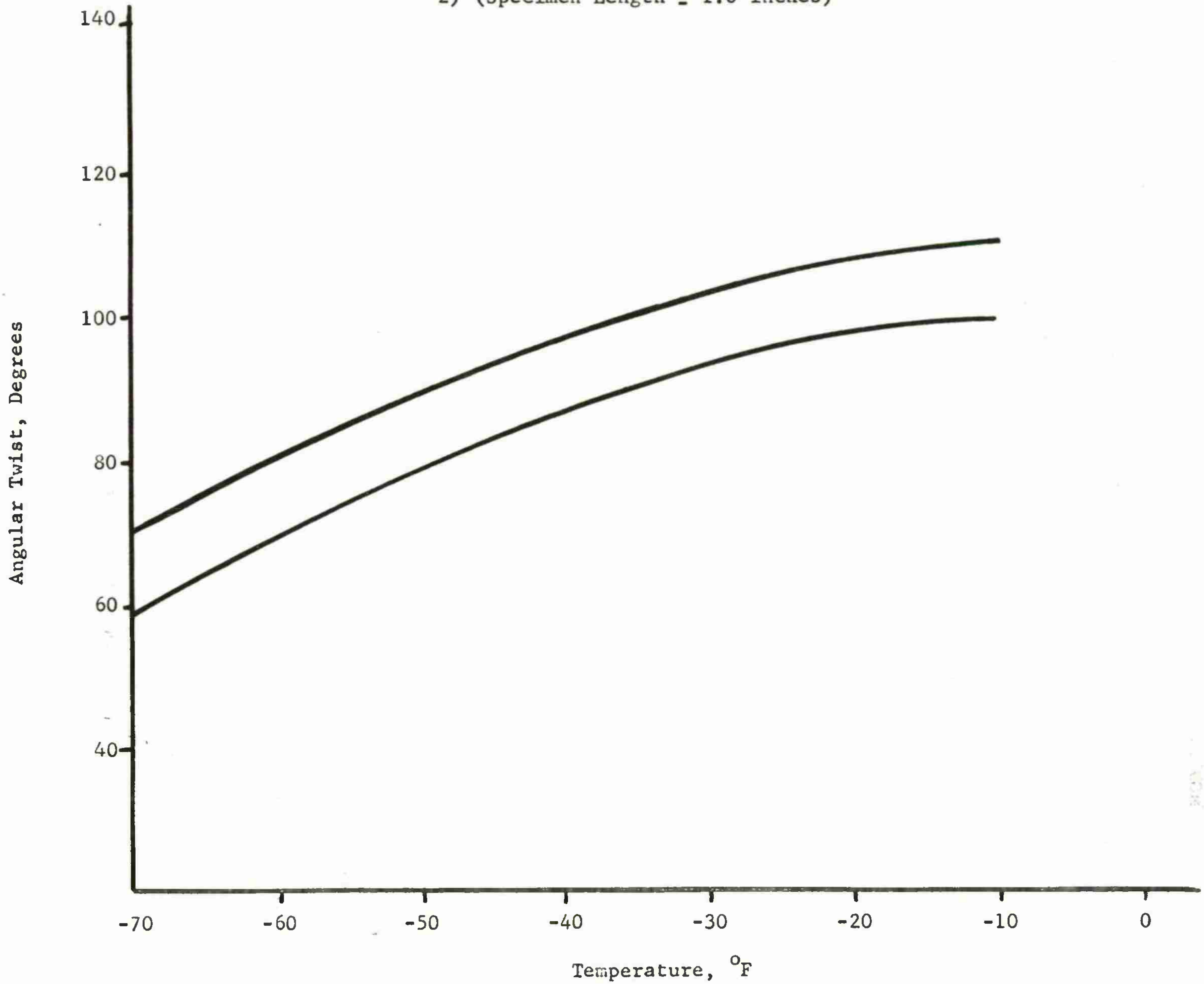


Figure 2 Reproducibility of Twist vs. Temperature Curves for a Vinyl-Coated Dacron Fabric (12, Table 2) (Specimen Length = 1.5 inches)

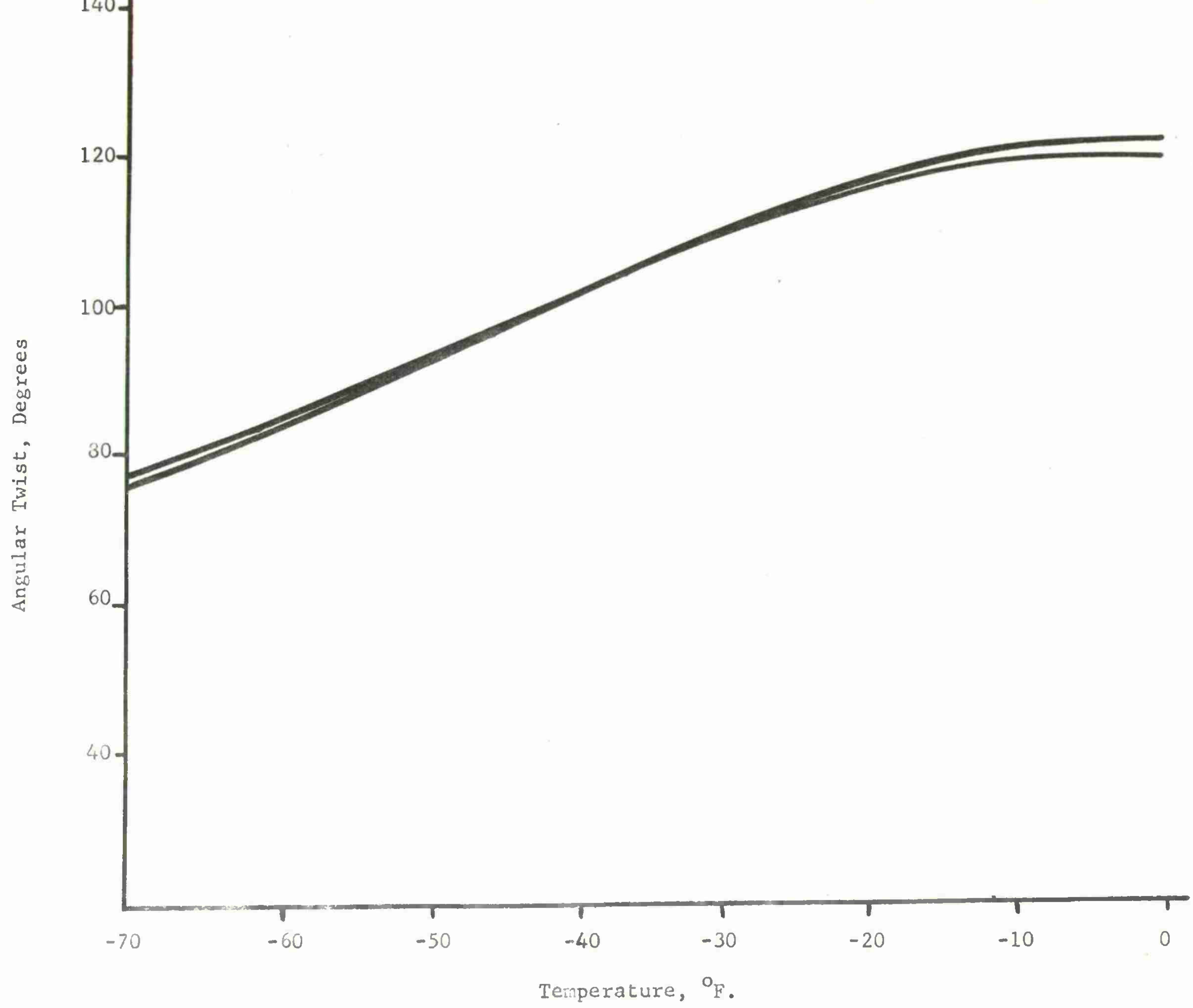


TABLE 3

COATED FABRICS TESTED PER MODIFIED ASTM D1053 IN INTER-LABORATORY ROUND-ROBIN

Coated Fabric	Coating/Substrate	Total Thickness inches	Weight[3] oz/yd^2
A	Hypalon/Nylon	0.019	16
B	Vinyl/Nylon	0.025	18
C	Neoprene/Nylon	0.050	42
D	Nitrile/Cotton Duck	0.057	43

Figure 3 Reproducibility of Twist vs. Temperature of a Hypalon-Coated Nylon Fabric (A) in Inter-Laboratory Tests

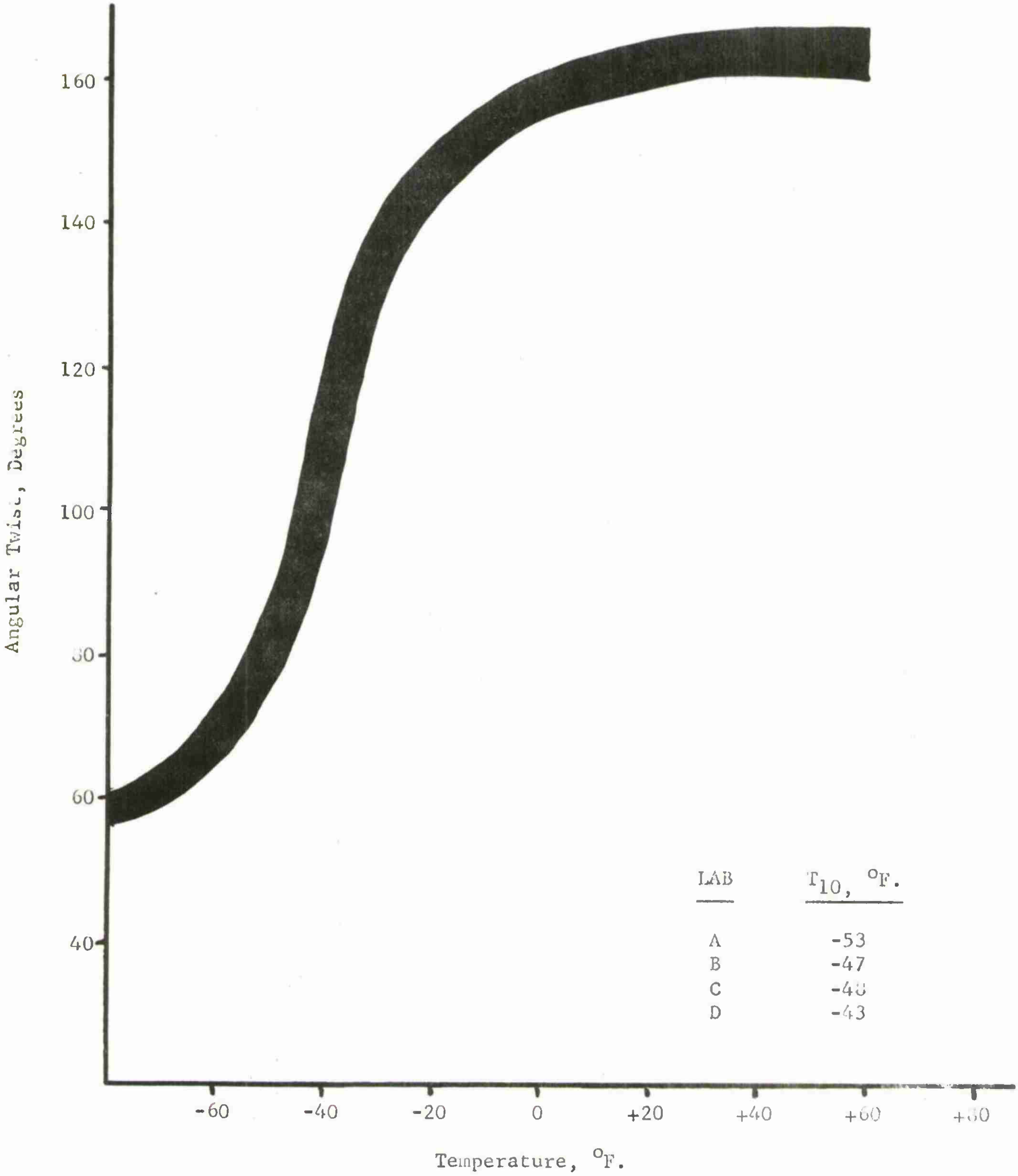


Figure 4 Reproducibility of Twist vs. Temperature of a Vinyl-Coated Nylon Fabric (B) in Inter-Laboratory Tests

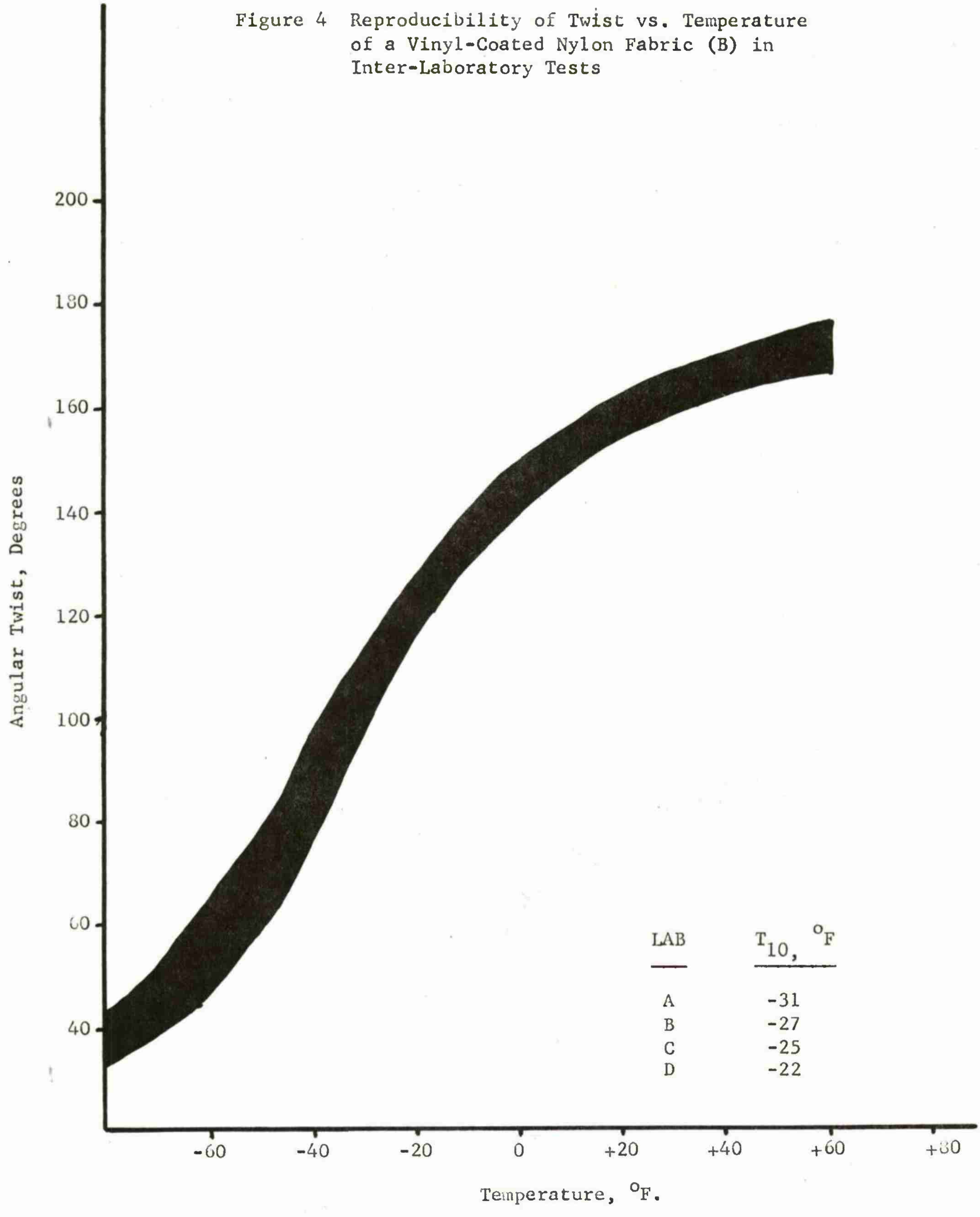


Figure 5 Reproducibility of Twist vs. Temperature of a Neoprene-Coated Nylon (C) Fabric in Inter-Laboratory Tests

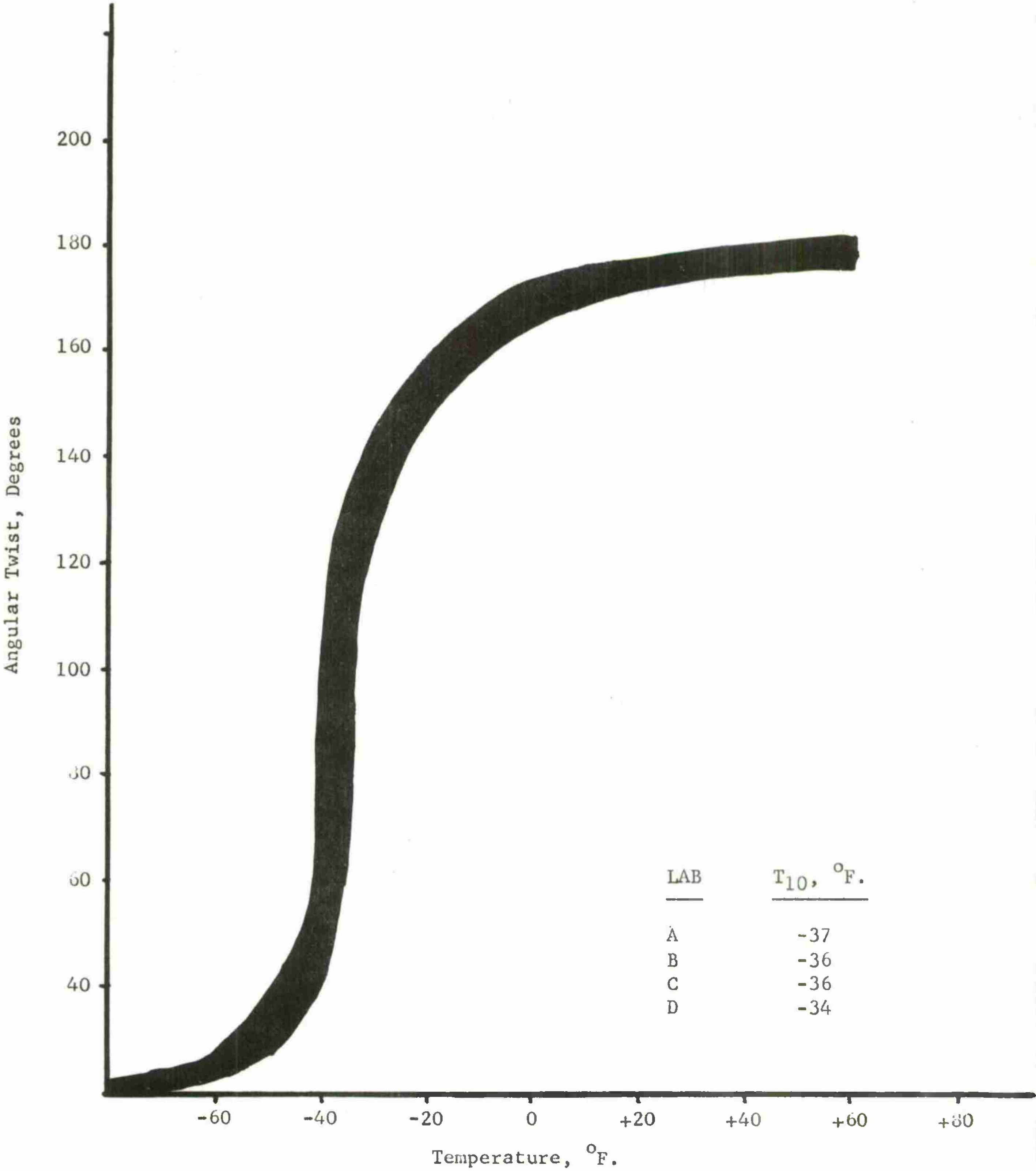


Figure 6 Reproducibility of Twist vs. Temperature of a Nitrile-Coated Cotton Duck Fabric (D) in Inter-Laboratory Tests

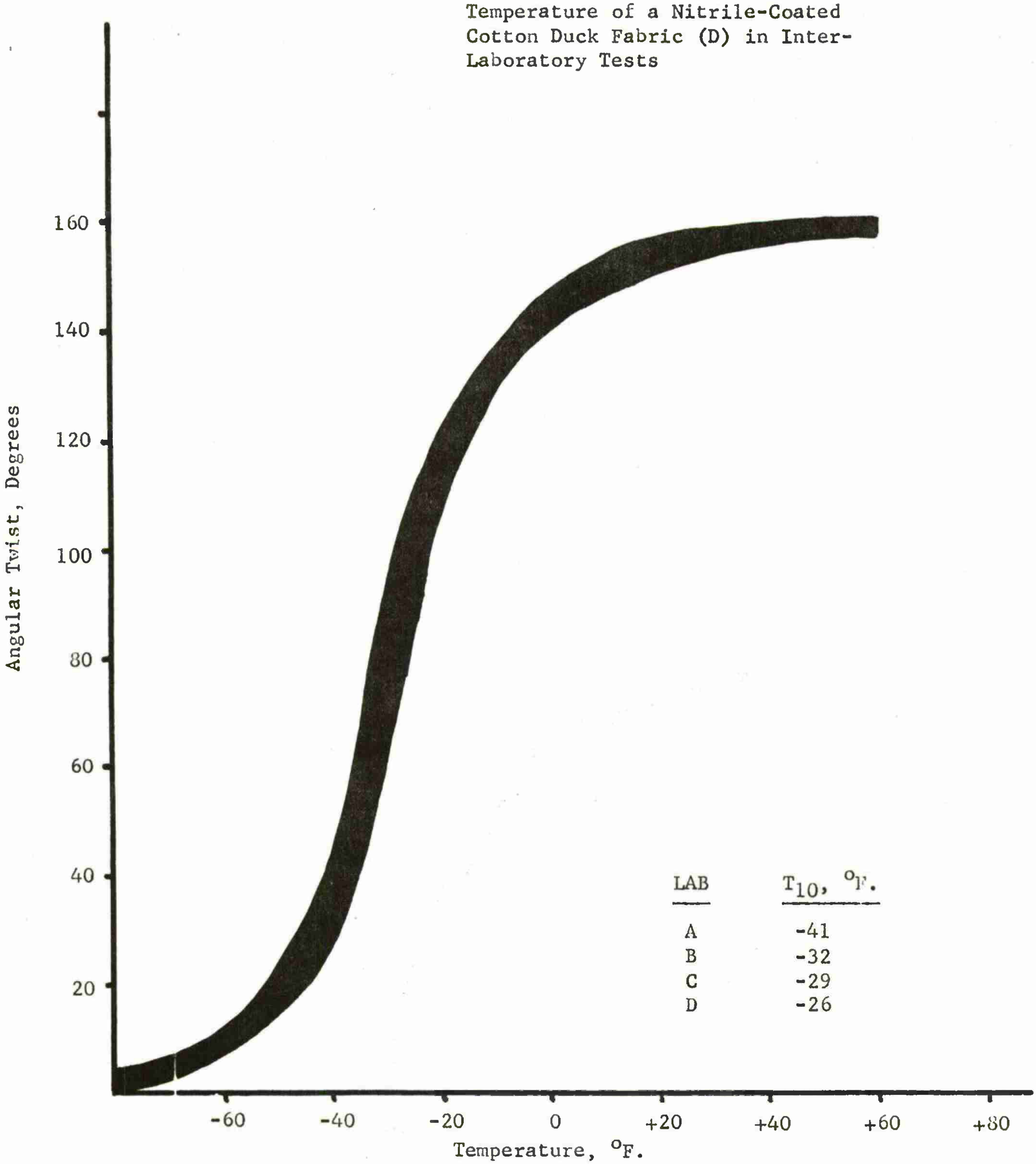
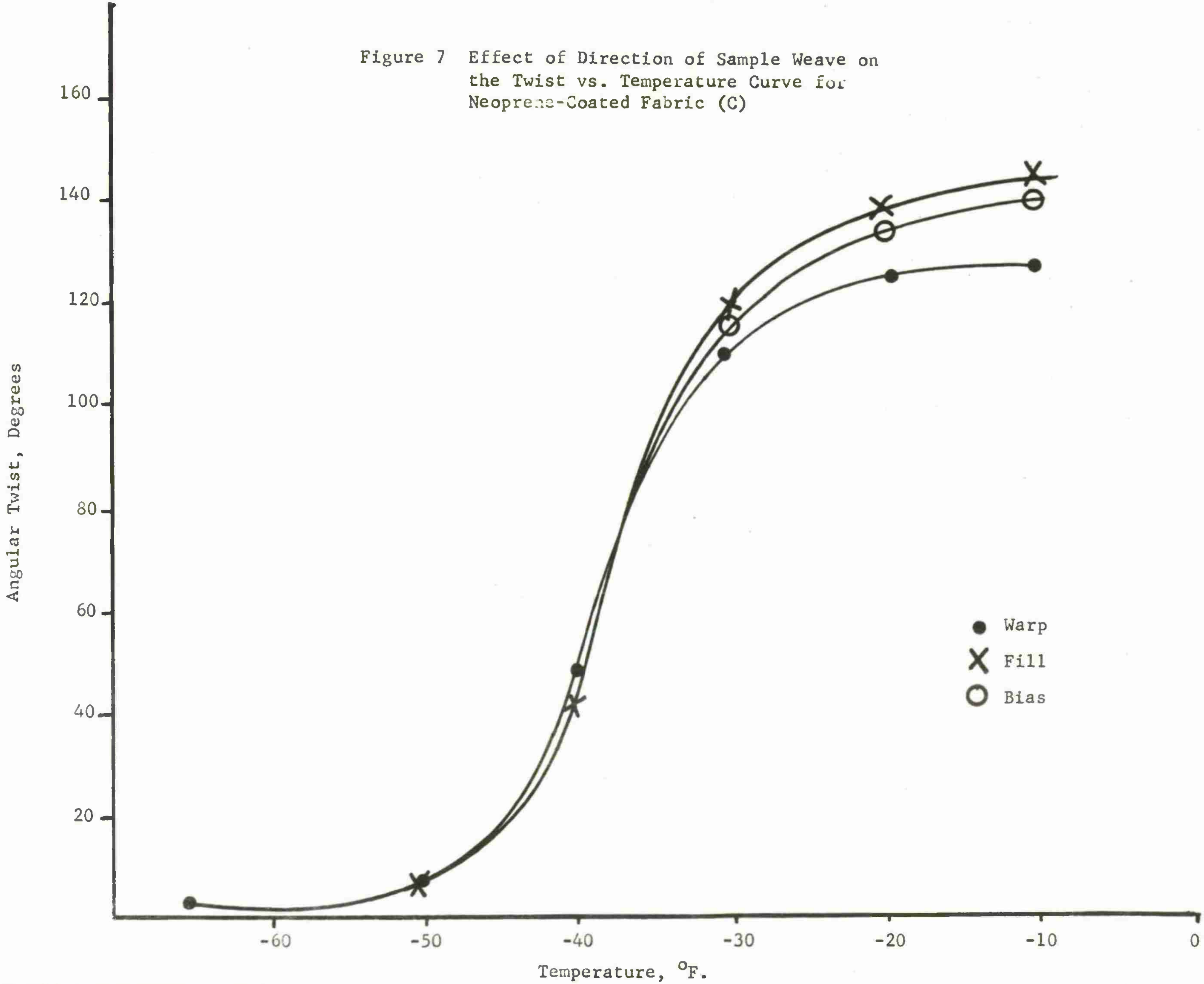


Figure 7 Effect of Direction of Sample Weave on the Twist vs. Temperature Curve for Neoprene-Coated Fabric (C)



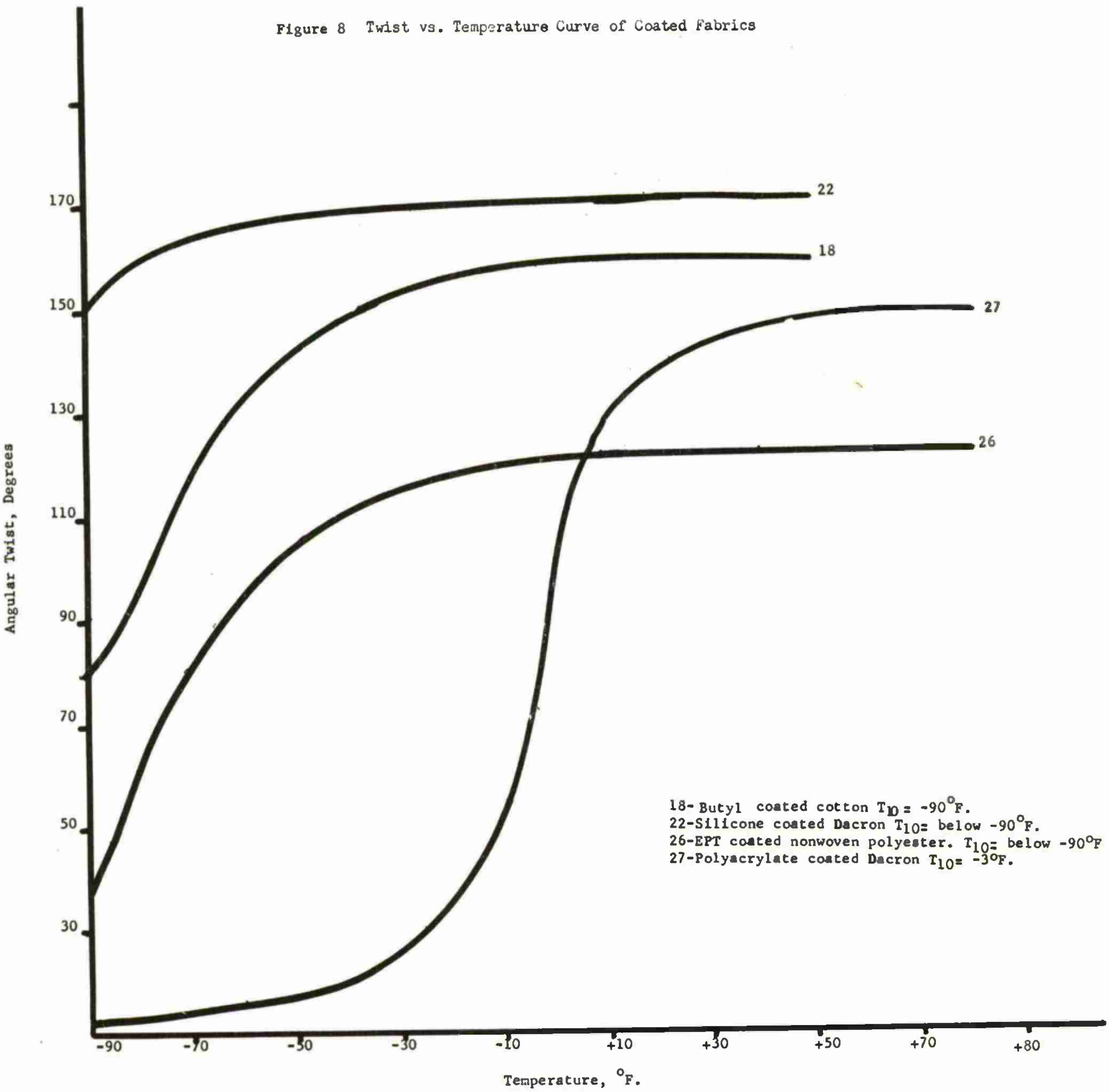


Figure 8 Twist vs. Temperature Curve of Coated Fabrics

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A TEST METHOD FOR MEASURING THE STIFFNESS OF COATED FABRICS AT LOW TEMPERATURES,
by Richard A. Faoro

Report R-TR-76-001, Sept 75, p. incl. illus. tables, (PRON A1-2-P6350-AW-M1, AMS CODE 4931.OM.6350) Unclassified report.

A test method was developed for use in determining the stiffness of plastic and rubber-coated fabrics at low temperatures by use of a torsional wire apparatus. From the test data obtained with this method, angular twist versus temperature curves can be prepared, and the temperatures at which the relative moduli of the coated fabric are 2,5,10, and 100 times as large as the modulus at room temperature can be determined. The method has been accepted by the American Society of Testing and Materials and has been published as ASTM D3388-75.

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